Efficacy of CC Traps and Seasonal Activity of Adult *Bemisia argentifolii* (Homoptera: Aleyrodidae) in Imperial and Palo Verde Valleys, California

CHANG-CHI CHU,[1] THOMAS J. HENNEBERRY,[1] ERIC T. NATWICK,[2] DAVID RITTER,[3] AND STEPHEN L. BIRDSALL[3]

Western Cotton Research Laboratory, USDA–ARS, 4135 E. Broadway, Phoenix, AZ 85040

J. Econ. Entomol. 94(1): 47–54 (2001)

ABSTRACT Adult whitefly *Bemisia argentifolii* Bellows & Perring trap (CC trap) catches were compared with suction type trap catches. CC trap catches were significantly correlated to the suction trap catches. Higher numbers of *B. argentifolii* adults were caught in CC traps oriented toward an untreated, *B. argentifolii*-infested, cotton field as compared with traps oriented toward Bermuda grass fields, farm roads, or fallow areas. CC trap catches at five heights above ground (from 0 to 120 cm) were significantly related to each other in choice and no-choice studies. CC trap catches were low in the Imperial and Palo Verde Valleys from late October to early June each of 1996, 1997, and 1998. Trap catches increased with increasing seasonal air temperatures and host availability. Trap catches were adversely affected by wind and rain. Abrupt trap catch increases of 40- to 50-fold for 1–2 d in late June to early July followed by abrupt decreases in adult catches suggest migrating activity of adults from other nearby crop sources.

KEY WORDS *Bemisia argentifolii, Bemisia,* CC trap, suction trap, yellow sticky card trap

WHITEFLIES HAVE BEEN an economic pest worldwide. *Bemisia argentifolii* Bellows & Perring, (=*B. tabaci* Strain B) appears to have a wider host range than the >540 plant species reported for *B. tabaci* (Gill 1992, Basu 1995). In most agricultural areas in the southwestern United States cotton, *Gossypium* spp., spring and fall melons, *Cucurbita* spp., cole crops, and various vegetable crops, in conjunction with weed and ornamental hosts, and annual alfalfa, provide a year-round source of plants for *Bemisia* shelter, food, and reproduction. This sequential occurrence of hosts is of particular concern because dispersal from one host to another has, in many cases, hampered management efforts.

Progress in understanding the factors affecting *Bemisia* flight behavior and dispersal has been made (Blackmer and Byrne 1993a, 1993b; Tonhasca et al. 1994; Blackmer et al. 1995; Byrne et al. 1995; Byrne and Blackmer 1996; Isaacs and Byrne 1998; Byrne 1999). However, additional information is needed before crop rotation patterns, spatial considerations for crop planting, and other cultural treatments can be used to increase host-free periods as a means to control whitefly populations.

Bemisia dispersal activity has been studied using yellow sticky card traps (e.g., Youngman et al. 1986, Byrne et al. 1995). The traps are difficult to handle, and sticky surfaces become ineffective when covered with dust or saturated with insects. The sticky trap is not reusable unless cleaned and recoated. We have developed and patented a *Bemisia* trap (CC trap) that overcomes these disadvantages (Chu and Henneberry 1998a, 1998b) (Fig. 1A). Previous studies have shown that CC trap catches are significantly related to yellow sticky card trap catches (Fig. 2) (Hoelmer et al. 1998) and to numbers of adults on cotton leaves at the same trap height positions (Table 1) (Chu et al. 1998).

In the current studies, we compared CC and suction trap catches to determine the efficacy of CC traps at different heights. We also studied the influence of vegetation type on CC trap catches, and determined the seasonal abundance of *B. argentifolii* adults in the Imperial and Palo Verde Valleys, CA.

Materials and Methods

CC - Suction Trap Comparisons. The CC trap used was as described elsewhere (Chu and Henneberry 1998a, 1998b; Chu et al. 1998). The suction trap, designed by Steve J. Castle (USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ) was similar to that reported by Johnson (1950) and made of 15 cm long, clear plastic cylinder with a 10.5 cm i.d.. One end of the cylinder had an inverted 7.5 cm long screen (52 mesh) cone and the other housed a 12 V fan (Panflow,

[1] Western Cotton Research Laboratory, USDA–ARS, Phoenix, AZ 85040.

[2] University of California Desert Research and Cooperative Extension Center, Holtville, CA 92250.

[3] Agricultural Commissioner's Office, Imperial County, El Centro, CA 92243.

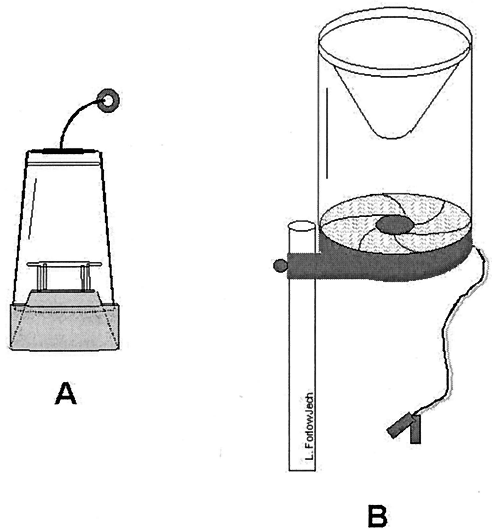

Fig. 1. CC (A) and suction (B) traps.

Matsushita Electric, Japan) powered by a 12 V motorcycle battery (Fig. 1B). Insects were trapped in the screened cone by the suction force (air current) of 5.7 km/h.

The experimental design for the trap comparison study was a randomized complete block (RCB) with five replicates. The two trap types were placed in each of the four cardinal directions on the border of a 3.2-ha cotton field that was not been treated with insecticides. In each cardinal direction there were five raised field borders (blocks, 18 m long), each was divided into two plots (9 m long). A CC or suction trap was placed in the center of each plot. Entrances of both trap types were 140 cm above the ground. Traps were exposed for 4-h periods from 0700 to 1100 hours PST each day for a total of 55 d from 14 May to 16 August 1996. Adult *B. argentifolii* were removed from the traps and counted. The 55-d trap catch averages were analyzed using analysis of variance (ANOVA) for a RCB design with cardinal directions and trap types as treatments. Regression analyses ($Y = \alpha + \beta x + \varepsilon$, $n = 55$) were made to compare the relationships between the *B. argentifolii* catches of the two trap types.

CC Trap Height Catches in a Fallow Field. The effect of trap height on CC trap catches was studied by placing traps in a harvested cotton field at Brawley, CA, 1996. No green leaves were visible on the harvested cotton plants, and the field was free of other vegetation. The experiment was a RCB design with ten replicates. Each replicate had six plots, five for no-choice and one for choice trap height treatments. Each plot was 144 m^2 (12 by 12 m). For the no-choice trap height, each trap was suspended on a wooden stake and placed at the center of the plot in the row furrows. Trap heights, measured from the cotton beds to the bottom edge of trap base, were 0, 30, 60, 90, and 120 cm (Fig. 3A). For the choice study, five traps were placed on an individual wooden stake at the trap heights described for the no-choice study (Fig. 3B). Traps were exposed for 24 h on each of 41 d from 19 August to 29 October 1996. Adult whitefly catches were counted after freezing. The 41-d catch averages were analyzed using ANOVA for a RCB design. Means were separated with Student–Neuman–Keul's multiple range test (Anonymous 1989). Correlations between trap catches at each trap height within and between no-choice and choice trap arrangements were determined.

Influence of Vegetation Type on Trap Catches. Five CC traps were placed 140 cm above the ground and 9 m apart in each of the four cardinal directions around a 3.2-ha cotton field. The cotton was insecticide-treated for *B. argentifolii.* The field was bordered on the east by 4.8 ha of Bermuda grass, on the west by 1.6 ha untreated cotton, and on the north and south by

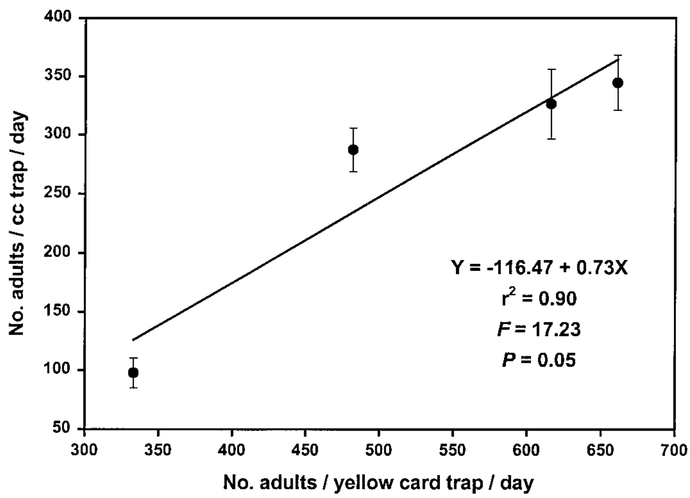

Fig. 2. Relationship between CC and yellow sticky card traps in a refugia for whitefly parasites (adapted from Hoelmer et al. 1998).

Table 1. Seasonal mean ± SE numbers of adult *Bemisia argentifolii* caught in CC traps in no-choice and choice studies or adults counted per cotton leaf at five heights in a cotton field at Maricopa, AZ, 1997

Variable	No. adults/trap/day or adults/10 leaves at each trap height (cm)				
	0	30	60	90	120
			No-choice study		
Adults/CC trap/day	25.1 ± 3.1d	41.1 ± 4.0d	101.4 ± 15.1c	152.7 ± 15.4b	212.8 ± 25.2a
Adults/10 leaves	24.7 ± 1.3c	31.2 ± 3.2c	45.7 ± 3.2c	111.4 ± 9.7b	196.1 ± 19.8a
Corr. coefficient	0.49	0.54	0.81	0.87	0.81
			Choice study		
Adults/CC trap/day	18.9 ± 2.4c	53.1 ± 4.9c	114.4 ± 10.0b	195.4 ± 11.3a	199.2 ± 13.5a
Adults/10 leaves	22.2 ± 2.0d	29.3 ± 2.0d	53.9 ± 3.2c	105.9 ± 6.4b	204.7 ± 8.4a
Corr. coefficient	0.10NS	0.28	0.48	0.65	0.54

Means within a choice or no choice type in a row not followed by the same letters are significantly different (Student-Neuman Keul's multiple range test, $P = 0.05$). $F = 20.9$ and 78.0 for trap catches for no-choice and choice study and 92.6 and 235.6 for adults per 10 leaves for no-choice and choice study, respectively, and df = 4, 36. All correlation coefficients are significant at $P = 0.01$. NS denotes not significant. (Adapted from Chu et al. 1998).

fallow fields over 5.0 ha and separated by 12-m wide farm roads. Traps were exposed for 24-h periods beginning at 0700 hours PST for a total of 29 d from 14 May to 16 August 1996. Average wind direction and speed in the test area were west at 5.22 km/h in May, west at 4.38 km/h in June, southeast at 4.22 km/h in July, and from the southeast and southwest at 4.68 km/h in August as recorded in the Bermuda grass field. Trap catches were compared with numbers of adults counted on five fifth leaf node leaves from terminals in 48 replicated plots in the described untreated- and insecticide-treated cotton plots on six sampling dates in July and August using the leaf-turn technique (Naranjo and Flint 1995). Data of 29-d CC trap catches

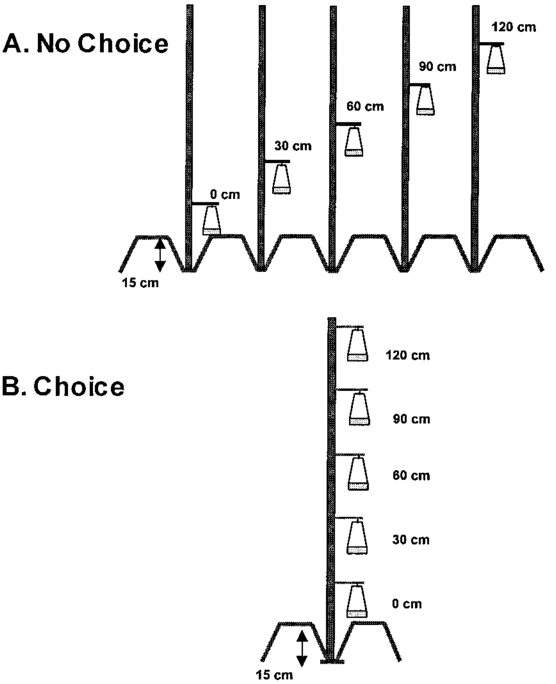

Fig. 3. No-choice (A) and choice (B) placement of CC traps in a fallow field.

as influenced by vegetation type and fallow lands were plotted and averaged.

Seasonal Trap Catches. Twenty-four CC traps were installed around the periphery of the Imperial Valley (Fig. 4). Six additional traps were placed along a north-south line through the central area of the valley. Traps, for easy accessibility, were located near the edges of farmlands, banks of irrigation canals, or roadways. In the Palo Verde Valley, 68 km northeast of the Imperial Valley, 10 traps were placed at locations oriented from the north to the south end the narrow valley. Traps were suspended 1.4 m above ground on wooden stakes, and were separated by at least eight and three km for Imperial and Palo Verde Valleys, respectively. Traps were replaced every 7 d from March 1996 to December 1998 in the Imperial Valley and from March 1997 to December 1998 in the Palo Verde Valley. Numbers of adults in each trap were counted after they died in the traps. The traps were installed and maintained by personnel of the Imperial County Agricultural Commissioner's Office, El Centro, CA. Mean monthly air temperatures recorded in Imperial, CA, and acreage of major crops that was susceptible to *B. argentifolii* colonization during the study were provided by the Imperial Irrigation District and County Agricultural Commissioner's Office, El Centro, CA, respectively.

Weekly adult catches were averaged for the Imperial and Palo Verde Valleys, respectively, and the means were plotted to show seasonal distributions. Mean monthly air temperatures and major crop growing periods were superimposed on weekly adult catches to show the relationships between adult populations and temperatures in general.

Results

CC - Suction Trap Comparisons. Numbers of adults caught in CC traps were significantly lower compared with suction traps placed in each cardinal direction around cotton (Table 2). Regression relationships between captures by CC and suction traps were low but statistically significant for each cardinal direction, as

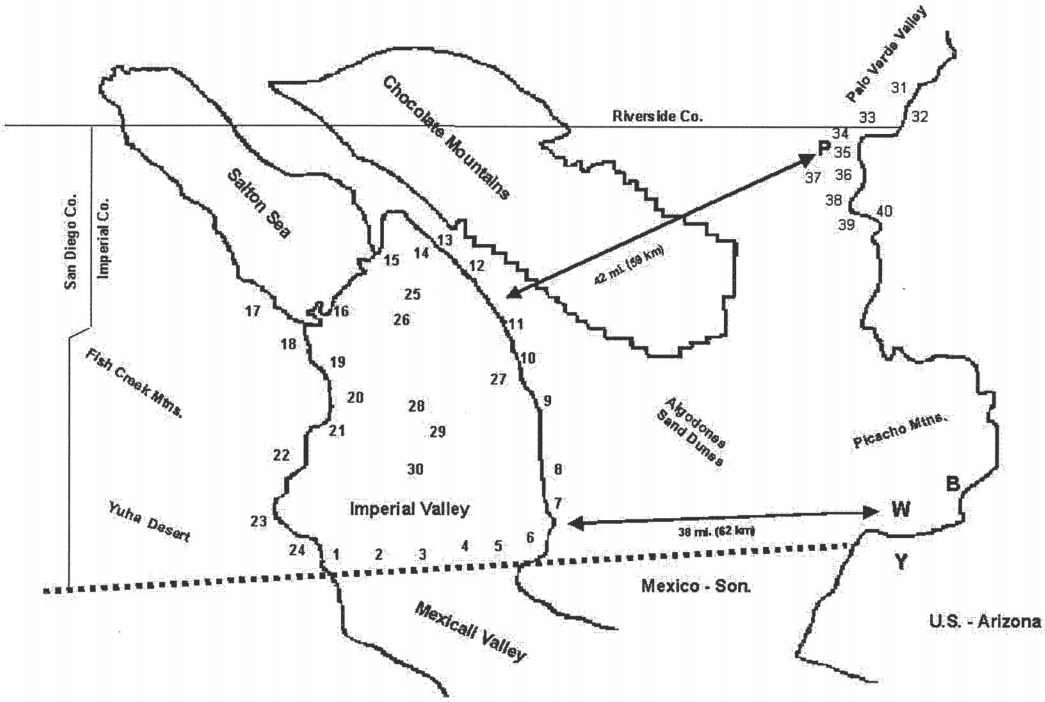

Fig. 4. CC trap locations for *B. argentifolii* surveys in Imperial and Palo Verde Valleys, CA, in 1996, 1997, and 1998.

well as, for the overall trap catch means ($r^2 = 0.27$–0.48, $n = 55$, $P = 0.01$).

CC Trap Height Catches in a Fallow Field. In the no-choice trap study, ground level traps caught the highest number of adults (32.2 adults/trap/24 h), followed by traps placed at 30, 60, and 90–120 cm above ground (Table 3). In the choice trap study, ground level traps also caught the highest number of adults (19.2 adults/trap/24 h) followed by traps placed 30 cm, and 60–120 cm above ground. Choice traps caught fewer adults compared with no-choice trap catches at 0-, 30-, and 60-cm trap heights, but not at 90- and 120-cm heights. The correlation coefficients were significant at each level of trap height within and between no-choice and choice studies, and ranged from $r = 0.54$–0.96 ($n = 10$, $P = 0.01$, Table 4). Also catches in no-choice and choice traps at each height were significantly related ($r = 0.54$–0.89, $n = 10$, $P = 0.01$).

Influence of Vegetation Types on Trap Catches. The mean numbers of adult *B. argentifolii* caught per trap during 29 exposure periods (24 h each) from 14 May to 16 August were higher for traps placed next to infested, untreated cotton (15.70 ± 2.65 adults/trap/d) compared with traps placed next to Bermuda grass or fallow fields (9.24 ± 1.56, 10.11 ± 1.89, and 8.56 ± 1.55 adults/trap/d, respectively). From 14 May through 5 June, numbers of adults per trap per day averaged less than one, except on 14 May in traps placed next to untreated cotton (Fig. 5). Catches increased slightly from 6–27 June, followed by abrupt increases of 80–110 per trap per day on 3 July 1996 in all traps placed around the untreated cotton field. Trap

Table 2. Mean ± SE numbers of adult *Bemisia argentifolii* caught in CC and suction traps placed around cotton fields in four different directions from 0700 to 1100 hours from 14 May to 16 August 1996 at Brawley, CA

Trap direction	No. adults/trap/4h			
	CC trap (Y)	Suction trap (X)	Regression	r^2
West	3.3 ± 0.2b	19.6 ± 1.2a	Y = 0.85 + 0.12X	0.30
North	2.9 ± 0.3b	9.2 ± 0.8a	Y = 1.01 + 0.21X	0.27
East	2.2 ± 0.2b	13.7 ± 1.3a	Y = 1.00 + 0.09X	0.40
South	1.9 ± 0.2b	9.7 ± 0.9a	Y = −0.12 + 0.20X	0.48
Direction mean	2.6 ± 0.1B	13.0 ± 0.6A	Y = 0.47 + 0.16X	0.39

Means of trap location or overall trap means not followed by the same letters are significantly different. $F = 162.5, 45.8, 185.6, 26.8$, and 166.9 for west, north, east, south and overall trap means, respectively, and df = 1, 4. All regression coefficients are significant ($n = 55$, $P = 0.01$).

Table 3. Mean ± SE numbers of *Bemisia argentifolii* adults caught with CC traps placed at five heights from top of cotton beds in no-choice and choice trap study in a fallow field from 19 August to 29 October, Brawley, CA, 1996

Trap, cm	No-choice	Choice
0	32.2 ± 4.3a	19.2 ± 0.3b
30	18.5 ± 1.0b	12.5 ± 0.6cd
60	15.1 ± 0.7bc	8.6 ± 0.3d
90	11.4 ± 0.5cd	7.9 ± 0.2d
120	10.6 ± 0.2cd	8.5 ± 0.4d

Means within choice and no choice column not followed by the same letters are significantly different (Student-Neuman-Keul's multiple range test, $P = 0.05$). $F = 24.8$ and df = 9, 45.

Table 4. Correlation coefficients relating *Bemisia argentifolii* trap catches at different heights in choice and of no-choice study in a fallow field from 19 August to 29 October, Brawley, CA, 1996

Trap, cm	Trap, cm[a]				
	0	30	60	90	120
		Choice study			
0	—	0.74	0.70	0.64	0.61
30	—	—	0.96	0.97	0.92
60	—	—	—	0.97	0.94
90	—	—	—	—	0.96
		No-choice study			
0	—	0.68	0.58	0.57	0.54
30	—	—	0.95	0.94	0.91
60		—	—	0.95	0.95
90	—	—	—	—	0.96
Choice vs no-choice	0.54	0.88	0.89	0.88	0.73

All correlation coefficients are significant at $P = 0.01$.
[a] Measured from top of beds.

catches in all traps decreased dramatically within 2 d following the peak catches. In July and August, respectively, the mean numbers of adults per leaf counted with the leaf-turn method were 21.8 ± 0.8 and 14.9 ± 0.9 in the untreated cotton, compared with 4.6 ± 0.6 and 8.4 ± 1.0 adults in insecticide treated-cotton.

Seasonal Trap Catchs. Imperial Valley. In the Imperial Valley, numbers of adult *B. argentifolii* caught in traps were low from 29 March to 11 May 1996, ranging from 0 to 0.5 adults/trap/wk (Fig. 6A). Mean numbers of adults caught increased from 0.5 to 3.6/trap/wk during the 7 June count and from 3.0 to 8.4/trap/wk during 12 July count. A peak catch of 59.1/trap/wk occurred on 2 August. Trap catches declined to 9.2/trap/wk on 20 September and increased thereafter to a second peak of 46.1/trap/wk on 11 October. From 24 October to 13 December, the numbers of adults caught ranged from 0.1 to 1.8/trap/wk. No adults were caught from 20 December 1996 to 15 April 1997.

In 1997, numbers trapped remained low until 29 July (8.8/trap/wk) (Fig. 6B), followed by a gradual increase to a peak catch of 51.5/trap/wk on 9 September. Trap catches decreased to 21.6/trap/wk by 7 October and to 0.3/trap/wk by 14 October. No adults were caught from 11 November 1997 to 19 May 1998.

In 1998, the first adults were caught in the Imperial Valley, CA, on 26 May (0.1/trap/wk) (Fig. 6C). Numbers remained low throughout the season. On 28 July, 6.5/trap/wk were recorded followed by a small peak catch of 14.3/trap/wk on 25 August. Trap catches fluctuated thereafter to 7.4/trap/wk for 1 and 8 September, with catches of 15.6/trap/wk occurring on 22 September. Trap catches of 4.7/trap/wk occurred 13

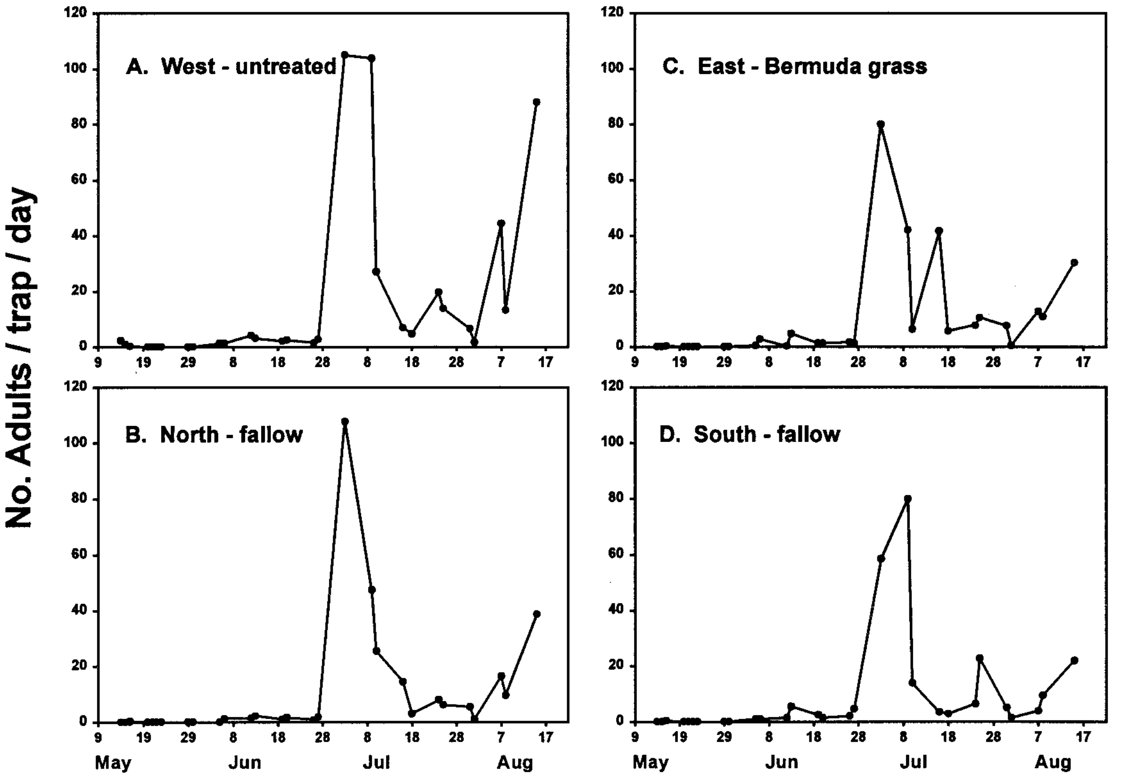

Fig. 5. Mean numbers of *B. argentifolii* adults caught on each sampling date in CC traps exposed for 24 h (0700–0700 hours) on the west (A), north (B), east (C), and south (D) field edges around an insecticide-treated cotton field at Brawley, CA, in 1996.

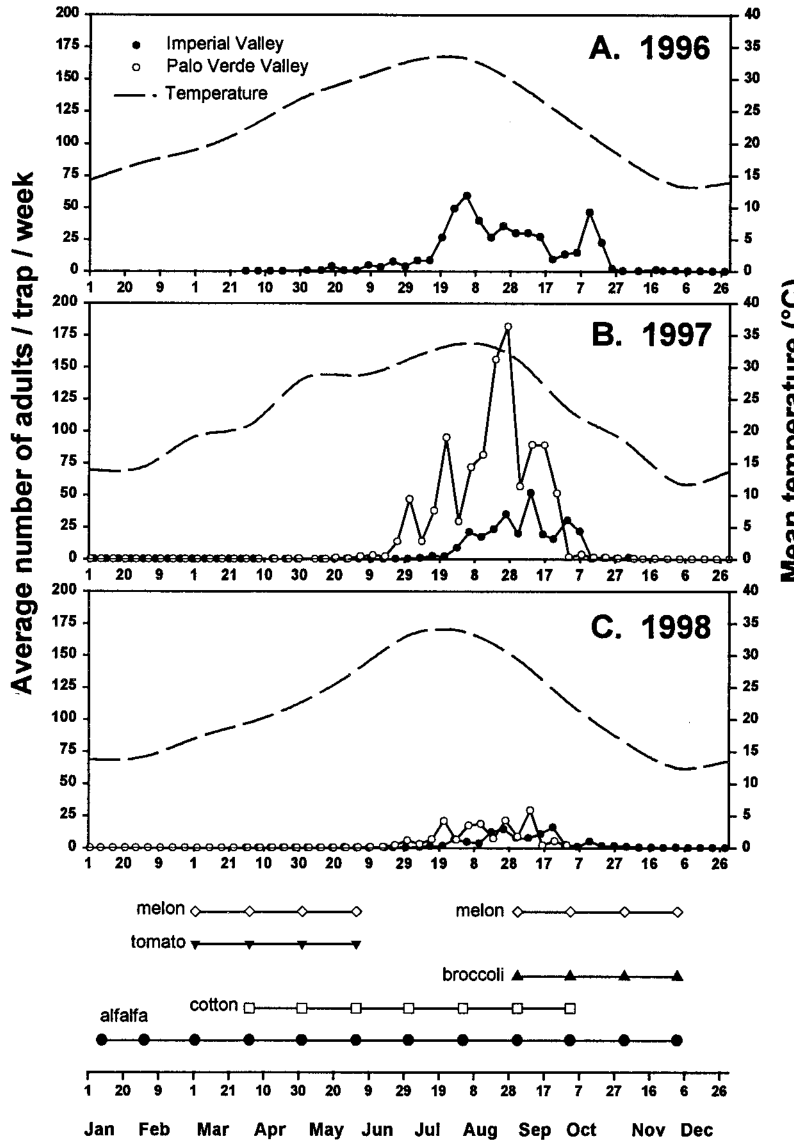

Fig. 6. Seasonal mean numbers of *B. argentifolii* adults caught in CC traps in Imperial and Palo Verde Valleys, CA, in 1996 (A), 1997 (B), and 1998 (C) and mean monthly air temperatures and sequentially occurring major cultivated crops.

October and fewer than two adults/trap/wk were caught from 20 October to 1 December. No adults were caught from 8 to 29 December 1998.

Palo Verde Valley. In 1997 and 1998, *B. argentifolii* trap catches were higher in the Palo Verde Valley than in the Imperial Valley (Fig. 6B and C). In 1997, no adults were caught until 30 April. Trap catches were low through early June, increased to 2–3/trap/wk in mid-June and to 13.7/trap/wk by 25 June. Numbers of adults caught peaked at 181.5/trap/wk on 27 August. Trap catches decreased thereafter to fewer than 4/trap/wk by 1 October. No adults were caught from 3 December 1997 to early June 1998. In 1998, adult catches ranged from 0 to 0.4/trap/wk from 3 to 17 June. Trap catches increased from 2 to 7/trap/wk between 24 June and 15 July. Peak catches occurred on 22 July, 26 August, and 9 September (20.7, 21.0, and 28.8/trap/wk). Numbers caught thereafter averaged fewer than 1/trap/wk from 7 October to 11 November. No adults were caught after 11 November.

Adult *B. argentifolii* activity peaks occurred during July, August, and September, when average air temperatures were 29°C or higher. Trap catches decreased when temperatures were decreasing during October through December and did not begin to increase again until June temperatures in the following year approached 28°C. The threshold temperature for adult *B. argentifolii* flight activity is unknown.

Discussion

CC whitefly trap catches were significantly related to the yellow sticky card trap catches and suction trap catches (Fig. 2 and Table 2). The relationships suggest that 90% of the yellow sticky card trap catches could be accounted for when replaced by CC traps. For suction trap catches, only 27–48% could be accounted for using CC traps. CC trap catches of 1.0 adult/trap/d would be estimated when yellow sticky card trap catches were 159.5 adults/trap/d (based on $Y = -116.47 + 0.73X$ and 93.75-cm^2 yellow sticky trap area, Fig. 2) (Hoelmer et al. 1998). Modifications have been made that increase CC trap catches by as much as 50% in a greenhouse study (unpublished data).

As expected, traps placed in closest proximity to *B. argentifolii* infested, untreated cotton caught more adults compared with traps near a Bermuda grass field or fallow fields (Fig. 4). A general dispersal of adult whiteflies occurred in July, probably migrating from matured spring melon fields. The dramatic reduction in numbers of adults trapped within 2 d after peak catches suggest that the activity was of short duration and adults settled in the cotton fields following dispersal.

Temperature has a major influence on adult whitefly activity (Coudriet et al. 1986, Isaacs and Byrne 1998). Historical weather records show that mean monthly air temperatures in the Imperial Valley are ≈14°C in January, increasing gradually to as high as 34°C in August, and decreasing gradually to ≈12°C in December (Fig. 6). Coudriet et al. (1986) caught *B. tabaci* adults on yellow sticky card traps in Imperial Valley during the winter months when average daily temperatures ranged from 13 to 15°C. In our studies, the last adult activity during each year of the study as measured by CC trap catches, occurred in December 1996, November 1997, and December 1998 when average daily air temperatures were 13.3, 18.3, and 13.4°C, respectively. Adults were first trapped thereafter on 5 April 1996, 22 April 1997, and 26 May 1998 when average air temperatures were ≈23, 26, and 21°C, respectively.

In addition to the effect of low temperature on flight activity, it is well known that adult and immature *Bemisia* populations decrease dramatically and oviposition and reproduction are greatly reduced on cultivated crops and weed hosts during fall and winter months (Gerling and Horowitz 1984, Simmons and Elsey 1995). Skinner (1996) suggested that 16°C was the minimum temperature threshold for *B. argentifolii* reproduction. *B. argentifolii* has been shown to complete its life cycle on winter crops such as cabbage (*Brassica oleracea* L.) spp. and lettuce (*Lactuca sativa* L.) under greenhouse conditions in California (Zalom et al. 1995). Complete life cycles of *B. argentifolii* have also been found to occur in the Imperial Valley in the field on numerous winter weed hosts, including both monocotyledon and dicotyledon plants (Natwick and Bell 1992). Earlier reports on the successful completion of life cycles of *B. tabaci* in the Imperial Valley in winter months included identification of all developmental stages on carrot (*Daucus carota* L.), broccoli (*Brassica oleracea* L.), squash (*Cucurbita maxima* Dene.), egg plant (*Solanum malongena,* L.), guar (*Cyamposis tetragonolaba* (L.) Taub.), guayule (*Parthanium argentautm* A. Gray), and alfalfa (*Medicago sativa* L.) (Coudriet et al. 1985). The authors reported that at least one generation and a partial second has been observed on lettuce (*Lactuca sativa* L.) in winter months. An estimate of the number of empty pupal cases in the late fall indicated that one adult was produced for every 25 mature lettuce leaves or ≈5,000 adults per hectare of lettuce (Coudriet et al. 1985). Empty pupal cases in December on lettuce and reproducing populations on alfalfa, London rocket (*Sisymbrium irio* L.), and alkali mallow [*Sidi hederacea* (Doug.) Torr.] have also been reported in Yuma, AZ (Watson et al. 1992). Low-level egg and nymph populations were found to exist on collard (*Brassica oleracea* variety acephela de Condolle), mustard (*Brassica juncea* (L.) Czernj. & Cosson variety juncea), canola (*Brassica napus* L.), and turnip (*Brassica campestris* variety *rapa* L.) in the winter in South Carolina (temperature range 9.7–16.9°C) (Simmons and Elsey 1995). In the Imperial Valley, in addition to the weed hosts, year-round cultivation of alfalfa (67,000 ha/yr) and seasonal growth of cotton (≈3,400 ha), broccoli and other cole crops (*Brassica* spp.) (≈3,000 ha), and tomatoes (*Lycopersicon esculentum* L.) (≈300 ha) from March to June and melons (*Cucurbita* spp.) from March to June and August to November (6,670 ha) provide year-round continuity of food, shelter, and reproductive habitat for *B. argentifolii.* The lack of adult catches in traps from December through April suggests a combination of high adult winter mortality, below threshold temperatures for flight activity, low levels of crop production acreage and reduced *B. argentifolii* reproduction.

A number of other factors may also affect *B. argentifolii* flight activity. For example, dramatic reductions in trap catches occurred during and after wind and rain in July and October (e.g., hurricane Nora, 24–25 September and strong winds 6–7 October 1997) in our studies. Castle et al. (1996) showed that *Bemisia* adult activity was suppressed due to sprinkler irrigation. Adult catches occurred earlier in the year in 1996 than in 1997, and earlier in 1997 than in 1998. *B. argentifolii* population density as measured by our trap catches was lower in 1998 compared with 1997, and lower in 1997 compared with 1996. These changes in population density have not been explained, but a similar phenomenon occurred following epidemic outbreaks of *Bemisia* in Israel after its introduction as an exotic pest (Gerling and Henneberry 1999). Stansly (1999) suggested that the decline of *B. argentifolii* adult density in Florida over the past few years is due to three factors: biological agents, management, and the use of the systemic insecticide imidacloprid (Admire, Bayer AG, Kansas City, MO) for vegetable production. These same factors were also suggested by Natwick et al. (1999) for the decline of adult densities in Imperial County, CA. Although predictions are extremely risky, it appears that *B. argentifolii* explosive populations have decreased. The future role and intensity of *B.*

argentifolii as an economic pest in southwestern crop production systems remains unknown. However, the development of highly efficacious insecticides likely played a significant role in population decline and development of resistance could reverse this trend.

Acknowledgments

The authors thank Marcus A. Boykin for for his assistance in the field studies and Howard Jencks for his monitoring seasonal trap catches in Imperial and Palo Verde Valleys.

References Cited

Anonymous. 1989. MSTAT-C, version 1.2, Michigan State University, East Lansing, MI.

Basu, A. N. 1995. *Bemisia tabaci* (Gennadius) crop pest and principal whitefly vector of plant viruses. Westview, Boulder, CO.

Blackmer, J. L., and D. N. Byrne. 1993a. Flight behavior of *Bemisia tabaci* in a vertical flight chamber: effect of time of day, sex, age and host quality. Physiol. Entomol. 18: 223–232.

Blackmer, J. L., and D. N. Byrne. 1993b. Environmental and physiological factors influencing phototactic flight of *Bemisia tabaci.* Physiol. Entomol 18: 336–342.

Blackmer, J. L., D. N. Byrne, and Z. Tu. 1995. Behavioral, mophological, and physiological traits associated with migratory *Bemisia tabaci* (Homoptera: Aleyrodidae). J. Insect Behav. 8: 251–257.

Byrne, D. N., and J. L. Blackmer. 1996. Examination of short-range migration by *Bemisia,* pp. 17–28. *In* D. Gerling and R. T. Mayer [eds.], *Bemisia:* 1995 taxonomy, biology, damage, control and management. Intercept, Andover, Hants, UK.

Byrne, D. N., R. J. Rathman, T. V. Orum, and J. C. Palumbo. 1995. Localized migration and dispersal by the sweet potato whitefly, *Bemisia tabaci.* Oecologia 105: 320–328.

Byrne, D. N. 1999. Migration and dispersal by the sweet potato whitefly, *Bemisia tabaci.* Agric. Forest Meteorol. 97: 309–316.

Castle, S. J., T. J. Henneberry, and N. C. Toscano. 1996. Suppression of *Bemisia tabaci* (Homoptera: Aleyrodidae) infestations in cantaloupe and cotton with sprinkler irrigation. Crop Prot. 15: 657–663.

Chu, C. C., and T. J. Henneberry. 1998a. Development of a new whitefly trap. J. Cotton Sci. 1–6.

Chu, C. C., and T. J. Henneberry. 1998b. Development of a silverleaf whitefly (Homoptera: Aleyrodidae) trap. Recent Res. Dev. Entomol. 2: 47–54.

Chu, C. C., T. J. Henneberry, and E. T. Natwick. 1998. *Bemisia argentifolii* adults caught in CC whitefly traps at different trap heights and trap catch relationships to leaf-turn counts on cotton. Southwest. Entomol. 23: 259–268.

Coudriet, D. L., N. Prabhaker, and A. N. Kishaba, and D. E. Meyerdirk. 1985. Variation in the development rate on different hosts and overwintering of sweetpotato whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae). Environ. Entomol. 14: 516–519.

Coudriet, D. L., D. E. Meyerdirk, N. Prabhaker, and A. N. Kishaba. 1986. Bionomics of sweetpotato whitefly (Homoptera: Aleyrodidae) on weed hosts in the Imperial Valley, California. Environ. Entomol. 15: 1179–1183.

Gerling, D., and A. R. Horowitz. 1984. Yellow traps for evaluating the population levels and dispersal patterns of *Bemisia tabaci* (Homoptera: Aleyrodidae). Ann. Entomol. Soc. Am. 77: 753–759.

Gerling, D., and T. J. Henneberry. 1999. The status of *Bemisia* as a cotton pest: past trends and future possibilities, p. 170. *In* Book, World Cotton Research Conference, 6–12 September 1998, Athens, Greece. International Cotton Advisory Committee, Washington, DC (abstr.).

Gill, R. 1992. A review of the sweetpotato whitefly in southern California. Pan-Pac. Entomol. 68: 144–152.

Hoelmer, K. A., W. J. Roltsch, C. C. Chu, and T. J. Henneberry. 1998. Selectivity of whitefly traps in cotton for *Eretmocerus eremicus* (Hymenoptera: Aphelinidae), a native parasitoid of *Bemisia argentifolii* (Homoptera: Aleyrodidae). Environ. Entomol. 27: 1039–1044.

Isaacs, R., and D. N. Byrne. 1998. Aerial distribution, flight behaviour and eggload: their inter-relationship during dispersal by the sweetpotato whitefly. J. Anim. Ecol. 67: 741–750.

Johnson, C. G. 1950. The comparison of suction trap, sticky trap and townet for the quantitative sampling of small airborne insects. Ann. Appl. Biol. 37: 268–285.

Naranjo, S. E., and H. M. Flint. 1995. Spatial distribution of adult *Bemisia tabaci* in cotton and development and variation of fixed-precision sequential sampling plans for estimating population density. Environ. Entomol. 24: 261–270.

Natwick, E. T., and C. E. Bell. 1992. Lower Colorado River desert weed hosts of the sweetpotato whitefly. Cooperative Extension, University of California, Imperial County, El Centro, CA.

Natwick, E. T., N. Toscano, and D. Ritter. 1999. Silverleaf whitefly population survey and insecticide resistance monitoring 1999 spring. Pest-O-Gram, 12 July 1999. Cooperative Extension, University of California, Imperial County, Holtville, CA.

Simmons, A. M., and K. D. Elsey. 1995. Overwintering and cold tolerance of *Bemisia argentfolii* (Homoptera: Aleyrodidae) in coastal South Carolina. J. Entomol. Sci. 30: 497–506.

Skinner, R. H. 1996. Leaf temperature effects on *Bemisia argentifolii* (Homoptera: Aleyrodidae) oviposition. Environ. Entomol. 25: 1371–1375.

Stansly, P. A. 1999. Pest outbreaks with special reference to recently introduced pests in Florida, p. 45. *In* XIVth International Plant Protection Congress (IPPC), Jerusalem, Israel, 25–30 July 1999 (abstr.). Kenes, Organizers of Congress and Tour Operators Ltd., Tel Aviv, Israel.

Tonhasca, A., Jr., J. C. Palumbo, and D. N. Byrne. 1994. Distribution patterns of *Bemisia tabaci* (Homoptera: Aleyrodidae) in cantaloupe fields in Arizona. Environ. Entomol. 23: 949–954.

Watson, T. F., J. C. Silvertooth, A. Tellez, and L. Lastra. 1992. Seasonal dynamics of sweetpotato whitefly in Arizona. Southwestern Entomol. 17: 149–167.

Youngman, R. R., N. C. Toscano, V. P. Jones, K Kido, and Natwick. 1986. Correlations of seasonal trap counts of *Bemisia tabaci* (Homoptera: Aleyrodidae) in southeastern California. J. Econ. Entomol. 79: 67–70.

Zalom, F. G., C. Castane, and R. Gabarra. 1995. Selection of some winter-spring vegetable crop hosts by *Bemisia argentifolii* (Homoptera: Aleyrodidae). J. Economic Entomol. 88: 70–76.

Received for publication 21 April 2000; accepted 3 October 2000.